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Effects of Watering, Shading, and Size of Stock on Survival of Planted Lodgepole Pine

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During a summer with above-normal precipitation, watering, shading and size of stock had no significant effect on survival of planted lodgepole pine. During a summer with below-normal precipitation, however, shading increased survival significantly, and larger stock survived better than smaller stock.

Keywords: *Pinus contorta*, survival, forest regeneration (artificial), shading, water stress.

Adequate survival has been difficult to obtain with planted lodgepole pine (*Pinus contorta* Dougl.) on large clearcut areas on the Bighorn National Forest in north-central Wyoming. Observations in these plantations led to the presumption that high moisture stress resulting from drought was a major factor contributing to mortality.

Severe moisture stress in planted seedlings can be directly controlled by irrigating, but such practice is generally considered impractical in Rocky Mountain forests. Indirect methods of controlling water stress, in contrast, may be applicable under field conditions. One approach to controlling water stress has been shading (Otter 1964, Adams et al. 1966, 1967, Gordon 1970, Ronco 1970). Shading not only reduces water loss from the soil surface, but also decreases seedling transpiration (Stoeckeler 1970). Another method might be to control seedling size, since extensive root systems of large seedlings absorb soil mois-

ture more effectively than underdeveloped roots (Wahlenberg 1928, Kramer and Koslowski 1960).

The objectives of this study were to test the effects of treatments aimed at alleviating severe moisture stress, and to determine the reasons for plantation failure, with emphasis on evaluating the effectiveness of shading in reducing seedling mortality.

Methods and Materials

The study was designed as a 2³ factorial to test the effects of two levels of water, shade, and seedling size on survival. Seedlings were either irrigated at regular intervals during the first growing season to maintain a high level of soil moisture in the root zone, or they received no water other than natural precipitation. In the shade treatment, seedlings either were shaded by an 8-in wide cedar shingle inserted into the ground on the south side of the seedling at an angle such that the top of the shingle was directly over the tip of the seedling, or they received full sunlight. The two seedling sizes (above-average and below-average) were determined by estimating stem caliper and volume of roots and shoots.

Seedlings were 2+0 stock grown in the Mt. Sopris Nursery, Basalt, Colo., from seed collected on the Bighorn National Forest.

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Study areas were on two sites on the Bighorn National Forest, one near Webb Creek in the southern part of the Forest and the other near the East Fork of the Tongue River in the north. In the spring of 1973, 10 blocks were planted in each experimental area — Webb Creek was planted on June 6 and East Fork on June 12. Each block contained 80 seedlings arranged in 8 rows of 10 seedlings each. Spacing within and between rows was 4 ft. Treatments were then randomly assigned to rows within a block. Seedlings were watered at 2-week intervals during the summer of 1973 to maintain adequate soil moisture, but watering was discontinued during the summer of 1974. Thus, the effect of supplemental watering could be tested for only the first growing season and for any subsequent residual effect. Shading was discontinued after the 1974 growing season.

The experiment was replicated in 1974 on an identical set of blocks adjacent to those established in 1973; planting dates were June 20 and June 25, respectively, on the Webb Creek and East Fork areas. Seedlings in this planting were shaded during the summer of 1974. The proposed watering schedule could not be maintained, however, so analyses of the 1974 plantings were limited to comparisons of the effects of shade and size of stock.

Survival counts were made biweekly throughout the 1973 and 1974 growing seasons. In addition, a final observation was made in the fall of 1975 to determine any residual effect of shading and watering. The cause of mortality was recorded for individual seedlings whenever possible.

A hygrothermograph and a trough rain gage were installed on both experimental areas. Survival data were tested by analysis of variance using an arcsin transformation.

Results

1973 Plantings

Survival after two growing seasons on the Webb Creek plots averaged 94% over all treatments (table 1). None of the treatments had any significant effect on survival after two growing seasons, so data were combined for seedlings at above-average and below-average size. Similarly, none of the treatments significantly affected survival on the East Fork plots. Even at the end of the third growing season — during which seedlings were neither watered nor shaded — no significant differences in survival had developed among treatments on either the Webb Creek or

Table 1.—Percent survival of lodgepole pine seedlings on Webb Creek and East Fork during three growing seasons following spring planting in 1973 (n = 100)

Year	Treatments				Mean ¹
	Watered	Shaded	Watered and shaded	Control	
..... Webb Creek					
1973	98	98	100	98	98
1974	91	95	96	94	94
1975	84	90	91	88	89
..... East Fork					
1973	96	98	98	96	97
1974	94	94	96	90	93
1975	87	87	90	83	87

¹No significant differences ($P = .05$) between mean values.

East Fork plots, indicating an absence of any residual effects. Total survival after three growing seasons was 89% on Webb Creek and 87% on East Fork. There was no interaction between shade and water treatments.

1974 Plantings

At the end of the first growing season on the Webb Creek plots, shading had significantly increased survival: 96% compared with 86% for unshaded seedlings (table 2). Similarly, survival of shaded seedlings was 95% versus 81% for unshaded seedlings on the East Fork plots. Survival for all treatments was 91% on Webb Creek and 88% on East Fork.

Although shading was discontinued after the first summer, its residual effect was still significant on both study areas at the end of the second growing season. Furthermore, size of stock — which apparently had no effect on survival on the Webb Creek plots during the first summer — significantly affected survival after two growing seasons. Survival of above-average-size stock was 82%, while below-average-size stock averaged only 74%. Average survival after two summers was 78% on Webb Creek and 67% on East Fork. There was no interaction between size and shade treatments.

Causes of Mortality

Mortality due to browsing by big game animals and gophers was minimal during these experiments. The most extensive damage, in the 1973

Table 2.—Percent survival of lodgepole pine seedlings on Webb Creek and East Fork during two growing seasons following spring planting in 1974 (n = 100)

Year and size of stock	Treatments		
	Shaded ¹	Control	Mean ²
..... Webb Creek			
1974			
Above-Average	96	88	92 _a
Below-Average	95	84	91 _a
Mean ²	96 _a	86 _b	91
1975			
Above-Average	86	79	82 _a
Below-Average	80	69	74 _b
Mean ²	83 _a	74 _b	78
..... East Fork			
1974			
Above-Average	94	80	87 _a
Below-Average	96	82	89 _a
Mean ²	95 _a	81 _b	88
1975			
Above-Average	72	65	68 _a
Below-Average	75	58	66 _a
Mean ²	74 _a	62 _b	67

¹Shaded only during 1974 growing season.

²Unlike subscripts denote a significant difference ($P = .05$) between mean values.

Webb Creek planting, amounted to only 15 seedlings, or approximately 2% of the 800 seedlings planted (table 3). Of the identifiable causes of mortality, drought or water stress accounted for most of the losses on both study areas in all years.

Discussion and Conclusions

Neither the direct effects of watering on seedling survival, nor its applicability towards identifying water stress as a potential cause of mortality was determined in this study. Nevertheless, some conclusions can still be drawn regarding the basic hypothesis that drought is a critical factor in lodgepole pine plantations on the Big-

horn National Forest. It is obvious that, during years such as 1973 when rainfall is abundant and well distributed throughout the growing season, water stress is not likely to be a major cause of mortality. In fact, in these experiments, survival was still high after 3 years, even though one of them was dry. Conversely, plantations established in a dry year, such as 1974, can be expected to suffer greater losses from water stress. Furthermore, increasing mortality can be expected in subsequent years, apparently due to the residual effect of water stresses developed in seedlings during the first year after planting.

It appears that losses due to severe moisture stress can be significantly reduced simply by shading. During dry periods, shade most likely creates a more favorable internal water balance by decreasing evapotranspiration (Kramer 1969, Stoeckeler 1970). During wet years however, shade does not increase survival, presumably because adequate soil moisture prevents high moisture stress. During dry years, shade appears to be nearly as effective as maintaining adequate soil moisture in reducing losses from drought. Survival of shaded seedlings in the 1974 planting was 95% and 96% on the Webb Creek and East Fork plots, respectively. Thus, the maximum increase in survival obtainable in this year by watering shaded seedlings would apparently have been 4% to 5%.

The relationship between seedling size and survival was similar to that produced by shade, in that this treatment influenced survival only during dry years. Seedling size increased survival only for the 1974 planting when low precipitation of 0.2 and 0.9 in was recorded on Webb Creek and East Fork, respectively, during the 2- to 3-week period after planting. Contrary to normal expectations, however, no differences in survival due to seedling size were apparent the first year. Not until the second growing season, and then only on the Webb Creek plots which received the least precipitation, were any significant differences in survival observed. It appears, therefore,

Table 3.—Percent mortality in each experimental planting at the end of the 1975 growing season

Location and year planted	Cause of Mortality				
	Pocket gopher	Big game browsing	Drought	Unknown	Total
Webb Creek					
1973	1	1	3	6	11
1974	0	1	17	4	22
East Fork					
1973	1	1	5	6	13
1974	0	0	24	10	34

that larger stock survives better than smaller stock only under drought conditions on drier sites. Apparently, root systems of small seedlings absorb adequate moisture during wet years, but under drought conditions, water uptake is sufficient only in large seedlings with well-developed root systems.

The data also indicate that lodgepole pine can be successfully regenerated without special treatment when precipitation is plentiful during the subsequent growing season. During a dry year, however, survival of planted seedlings may be too low to insure satisfactory stocking unless the planting rate is increased or seedlings are irrigated or protected by shading.

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